(12) UK Patent Application (19) GB (11) 2 270 481 (13) A

(43) Date of A Publication 16.03.1994

(21) Application No 9219264.0

(22) Date of Filing 11.09.1992

(71) Applicant(s)
Rolls-Royce plc

(Incorporated in the United Kingdom)

65 Buckingham Gate, LONDON, SW1E 6AT, United Kingdom

(72) Inventor(s)
Darrell Lee Mann
Martin Berry
Colin George Pugh

(74) Agent and/or Address for Service
T C Jennings
Rolls-Royce plc, Patents Department, PO Box 31, Moor Lane, DERBY, DE2 8BJ, United Kingdom

(51) INT CL^5
B01D 45/04, F02C 7/052

(52) UK CL (Edition M)
B1T TPFK TPNB
U1S S1272 S1840 S1987

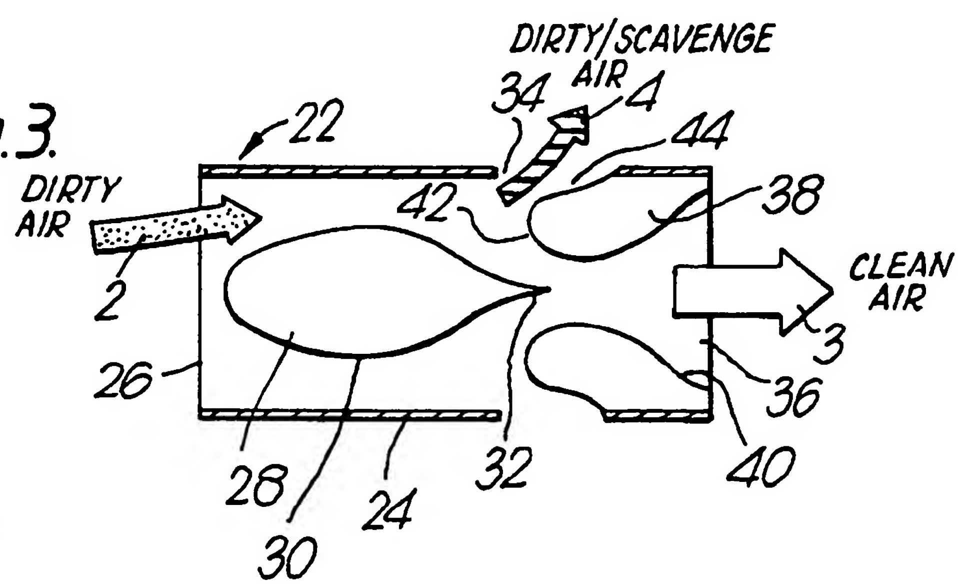
(56) Documents Cited
GB 2138318 A GB 1553526 A GB 1298793 A
GB 1101062 A US 4469497 A

(58) Field of Search
UK CL (Edition K) B1T TPFK TPGG TPNB
INT CL^5 B01D 45/04 45/06 45/12 45/16, F02C 7/052

(54) Particle separators

(57) A separator, for removing solid particles from the air intake of an aircraft gas turbine engine, comprises a panel array of separator units, each of which comprises a through duct enclosing an obturator which divides the air flow into a particle-rich fraction, which is discharged separately, and a particle-depleted fraction, which is passed to the engine. The unit in Fig. 3 comprises a duct 24 of circular section, which may be extended by an inlet of square or hexagonal section so that the inlets together cover the whole intake area of the panel. Outlet 34 for the particle-rich fraction comprises one or more holes, whose effective area may be adjusted by an external sleeve (Figs. 8, 9). In Figs. 5, 6 the ducts are of rectangular cross-section and the obturators extend parallel to each other and comprise cavities, which divert the particle-rich fraction to a common outlet. Flow dividers which define the ducts may carry adjustable flaps to vary the ratio between the two fractions (Fig. 7).

Fig. 3.



GB 2 270 481 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

Fig.1.

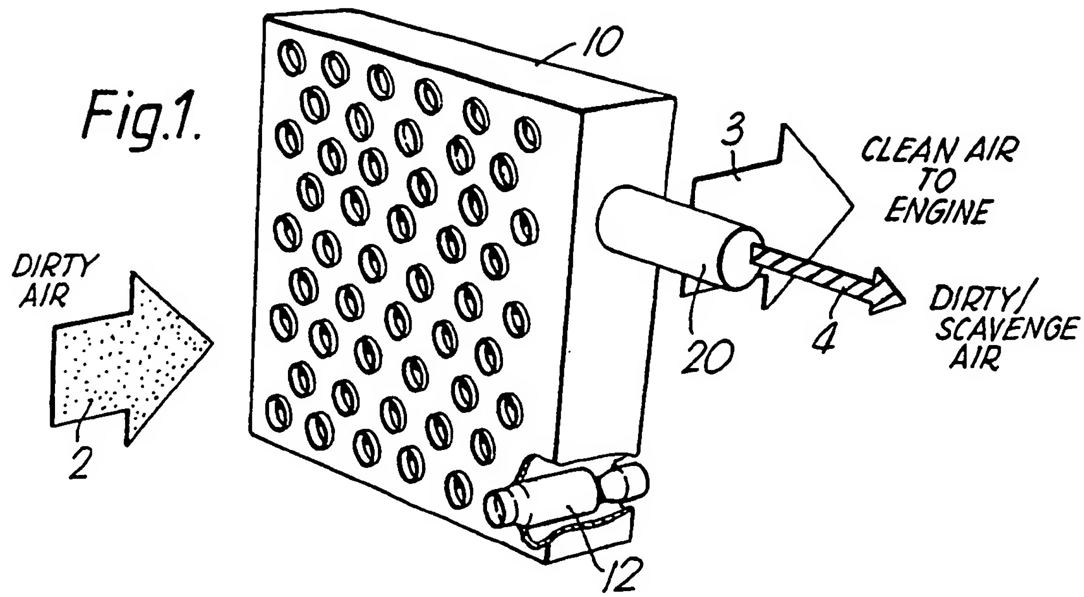


Fig.2.

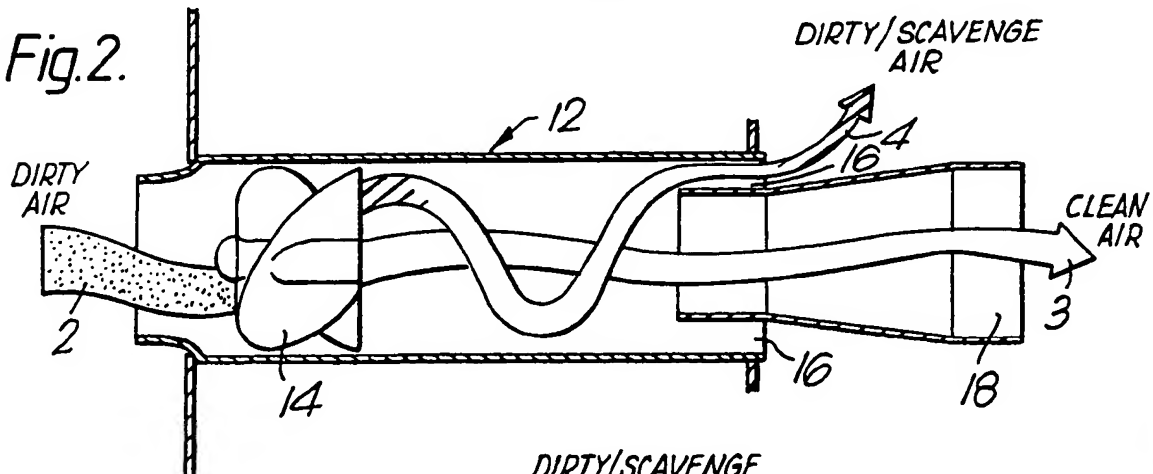


Fig.3.

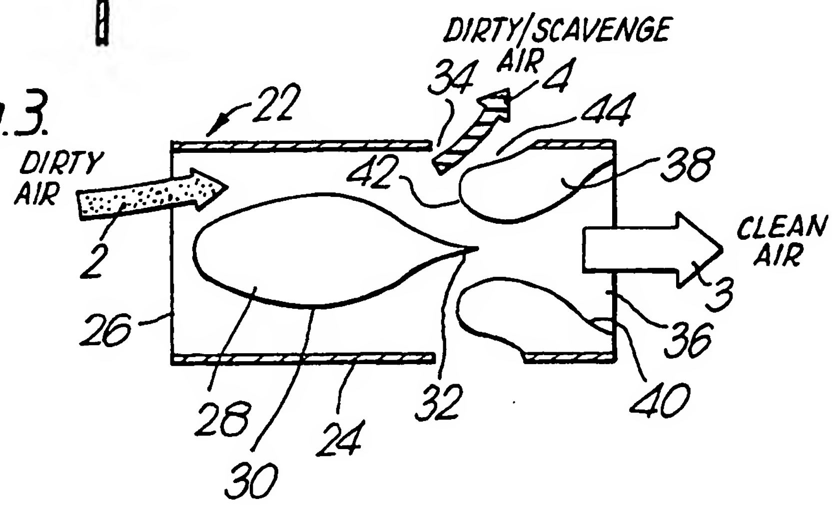


Fig.4.

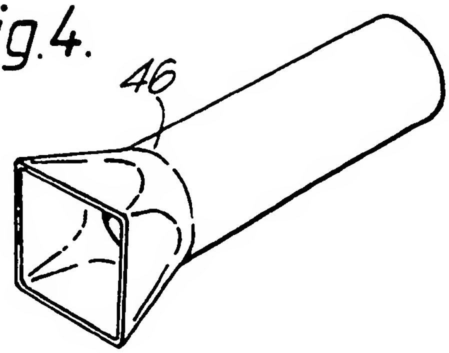


Fig.5.

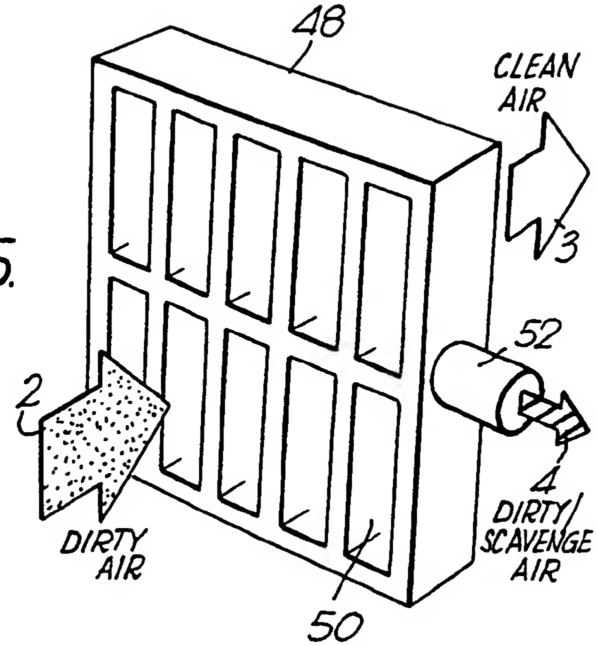


Fig.6.

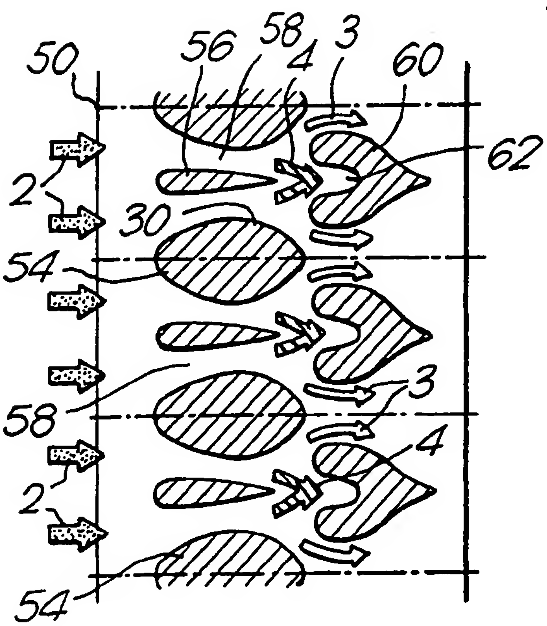


Fig.7.

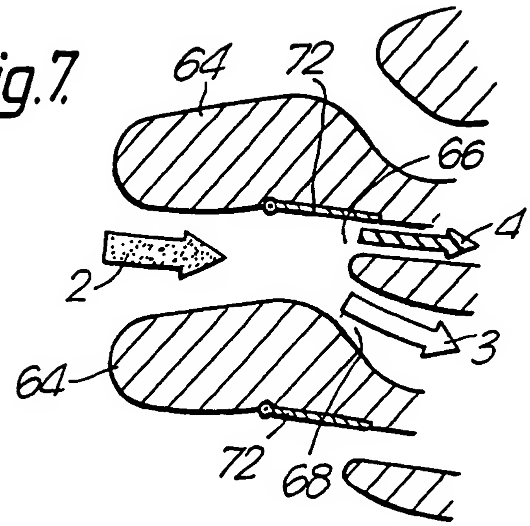


Fig.8.

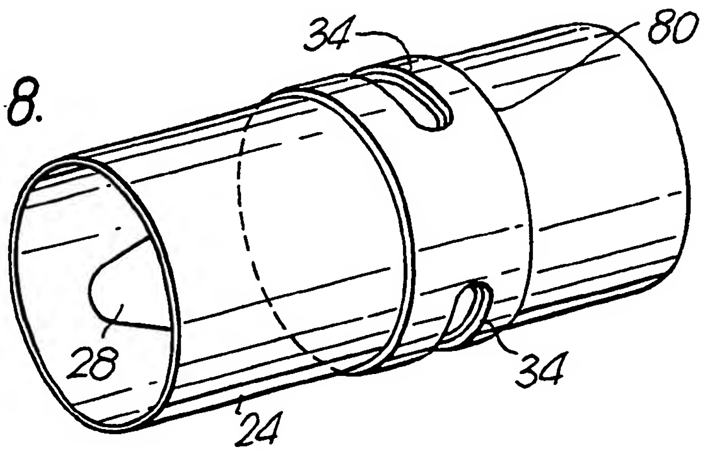
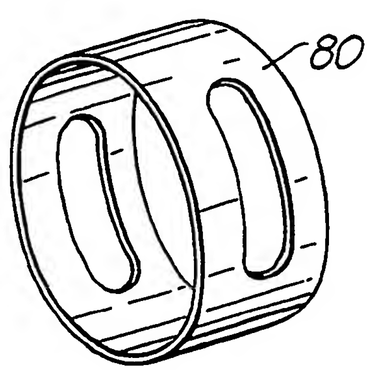


Fig.9.



IMPROVEMENTS IN OR RELATING TO PARTICLE SEPARATORS

This invention concerns engine air intake protection for an aircraft gas turbine engine, and concerns improvements to panel separators for separating particulate material from particle-containing air entering such an engine.

It has long been known that gas turbine engines used in aircraft are vulnerable to ingestion of foreign matter. In the case of helicopter engines, panel inertial separators are commonly used to limit the passage of particulate material such as sand and dust into the engine.

Experience of military helicopters in desert conditions shows that current intake protection systems (ie panel inertial separators) do not provide sufficiently good particle separation performance to meet military requirements, and that there is accordingly a need for significantly improved levels of efficiency in such systems.

Current panel inertial separators use spiral, or vortex, flow effects in a panel array of vortex tubes to separate dust and sand from the engine intake air.

Figures 1 and 2 of the accompanying diagrammatic non-scale drawings 1-8 show, respectively, a partly cut away oblique view of a known rectangular panel array 10 of known vortex tubes 12, and a longitudinal section through such a vortex tube 12.

In Figures 1 and 2, and in further figures particularly to various embodiments of the present invention, numeral

"2" will refer to incoming air containing particulate material, numeral "3" will refer to clean air leaving the system and passing to the engine, and numeral "4" will refer to dirty air scavenged from the system.

The vortex tube 12, as illustrated, is of circular section and is provided at its upstream end with a set of swirl vanes 14 which impart a swirling or vorticular motion to the incoming air stream. The inertial effects brought about by the swirling motion cause the particulate material entrained in the air stream 2 passing through the vortex tube 12 to be scavenged through an annular downstream outlet 16, whilst relatively clean air is ejected through an axially located outlet 18 into an engine (not shown).

Dirty air 4 scavenged from the vortex tubes 12 in the panel array 10 is finally ejected through an outlet 20 into the atmosphere or into a plenum chamber for subsequent ejection into the atmosphere.

The vortex tube method of separating particulate material, whilst attractive in theory, presents practical disadvantages, as follows:

a there is a reduction in primary intake pressure due to the formation and subsequent destruction of vortices,

b particle separation efficiency is reduced due to a multiple bounce nature of particle trajectories,

c there is not sufficient inertia at the hub of a vortex to bring about effective separation of some entrained particulate material in the vicinity of the axis of the vortex,

d the efficiency of separation bears an inverse relationship to the size of the entrained particles (it is the larger particles that are likely to cause the greater damage to an engine),

e full vortex formation is necessary for acceptable separation efficiency, and this requires a long vortex generator, thus increasing the overall size and weight of the vortex device,

f the vortex generation vanes (14 in Figure 2) act as an inlet blockage, typically of the order of 10% and it is necessary to increase the size of the overall device to compensate for this blockage effect,

g vortex generation vanes are prone to icing, especially if the vortex tubes face upstream of the engine,

h the overall panel intake area is not fully utilised because of the spaces between the circular cross-section vortex tubes,

i it is difficult to design a panel of vortex generators to provide even scavenging of particles by means of vortex tubes of different shapes and sizes, and

j there is no simple way of adjusting vortex tubes of different shapes and sizes so as to compensate for inherent imbalances of air flow through the tubes.

The present invention in its most general aspect addresses the above disadvantages by using non-spiral panel inertial separators.

According to the present invention there is provided a particle separator for separating particulate material from an inlet air stream to a gas turbine engine, the separator comprising a panel array of at least two axisymmetric non-spiral particle separators, each separator in the array including, (a) an inlet duct, upstream ends of the inlet ducts lying in a plane transverse of the inlet air stream, (b) first and second outlet duct means downstream of the inlet duct, the second outlet duct means providing air for the engine, and (c) an obturator arranged within the inlet duct to split the air stream in the inlet duct into first and second outlet streams, the first outlet stream having an increased content of particulate material, and the second outlet stream having a decreased content of particulate material, and to direct the first outlet stream to the first outlet duct means and the second outlet stream to the second outlet duct means.

The first outlet duct means is preferably arranged to direct the first outlet stream to a scavenge plenum chamber, and at an angle to the second outlet stream.

The inlet duct may be polygonal in cross-section at its upstream end and circular in cross-section at its downstream end, there being provided a transition region in the inlet duct from one cross-section to the other.

The upstream polygonal cross-section may be a polygon characterised in that a plurality of such polygons is capable of tiling a plane.

There may be provided a valve in the first outlet duct means whereby the ratio of the first outlet stream to the second outlet stream may be controlled.

The valve may be provided by an adjustable flap.

The second outlet duct means may provide an inlet stream to a second particle separator integrated with the first separator.

The invention will now be described by way of example only with reference to Figures 3-9 of the accompanying diagrammatic non-scale drawings, in which,

Figure 1 shows a partly cut away oblique view of a known rectangular panel array of known vortex tubes,

Figure 2 shows a longitudinal section through a vortex tube of Figure 1,

Figure 3 is a longitudinal section through a first embodiment of a separator tube according to the invention,

Figure 4 is an oblique view of a modification to the separator of Figure 3,

Figure 5 is an oblique view of further panel array of a second embodiment of separator tubes according to the invention,

Figure 6 is a longitudinal section through a stack of separator tubes of Figure 5, taken in the direction of arrow 6,

Figure 7 is a longitudinal section through a third embodiment of a separator tube according to the invention,

Figure 8 is an external oblique view of the separator tube of Figure 3 when provided with an external collar, and

Figure 9 is an oblique view of the collar of Figure 8 when removed from the separator tube.

Referring to Figure 3 there is shown an axisymmetric non-spiral inertial separator 22 for use in a particle separator according to the invention. The separator 22 comprises a cylindrical tube 24 provided with an inlet 26 at its upstream end for the ingestion of air 2 that may contain particulate material such as sand or dust. Within the tube 24 and located symmetrically about the tube axis is a flow divider 28. The flow divider 28 is an elongate structure having a radial cross-section which increases downstream to a maximum at a middle region 30 of the divider and then tapers rapidly to a minimum of the downstream end 32 of the divider.

Spaced round the cylindrical wall of the tube 24 in a region between the middle region 30 and the downstream end 32 of the divider 28 is at least one and preferably more than one circumferentially spaced scavenge outlet apertures 34 communicating with the interior of the tube. Only one such outlet aperture 34 is shown in Figure 3. The outlet apertures 34 provide an exit for dirty air 4 scavenged by the separator 22, as will be explained below.

The downstream open end of the tube 24 is provided with an axial outlet 36 which is defined within the tube by a frusto-conical annular flange 38 having its larger end 40 at least approximately co-terminous with the open end of the tube, and its smaller end 42 extending upstream within the tube so as to overlap and be spaced from the

downstream end 32 of the divider 28. The radially outer surface 44 of the flange 38 is shaped so as to direct a stream of dirty air 4 out through the outlet apertures 34; the radially inner surface of the small end 42 of the flange is shaped so as to cooperate with the downstream end of the flow divider 28 and to thereby define a path for clean air 3 to exit the tube 24 through the axial outlets 36.

The velocity of incoming dirty air 2 increases as it is funnelled between the flow divider 28 and the tube 24 until the air flow reaches the middle region 30 of the divider which is the region of maximum radial cross-section of the divider. Here the air flow will tend to follow the contour of the divider 28 into its rapidly tapering downstream section 32, by virtue of the coanda effect, into the axial outlet 36. However, particulate material in the incoming air stream 2 will, by virtue of its momentum, tend to go straight on into the outlet apertures 34 in the circumferential wall of the tube 24. Hence, particulate material will tend to be scavenged out of the separator 22 through the outlet apertures 34, and relatively clean air 3 will leave the separator through the axial outlet 36 and pass to the engine.

Referring now to Figure 4, there is shown a transition duct 46 for use with the separator 22 of Figure 3 when used at the panel front face in the array 10 of Figure 1. The transition duct 46 is shown with a square cross-section at its upstream end 48, and the square cross-section changes downstream into a portion 50 of circular cross-section which feeds dirty incoming air 2 into the separator 22. This enables the effective intake area over the array 10 to be maximised, and also increases the ram effect through the separator 22. Upstream cross-sections other than square may be

utilised, and it is preferably that such cross-sections be tileable on a plane so as to minimise or even reduce to zero total spacing between the peripheries of adjacent cross-sections and to maximise therefore the effective intake area. Simple examples of tileable configurations, in addition to the square mentioned above, are rectangles and regular hexagons.

Referring now to Figures 5 and 6 there is shown in Figure 5 what may be termed a "letter box" panel 48 consisting of an array of ducts 50 of constant rectangular section, which enables the panel area to be utilised more effectively than with a series of circular cross-section tubes. Dirty air 2 enters the front of the panel 48, is cleaned within the panel in a manner to be described below with reference to Figure 6, and clean air 3 exits from the rear, and dirty scavenge air 4 from the side via a scavenge port 52.

The ducts 50 are shown sectioned in Figure 6 and comprise a stack of flow dividers 54 of similar design to the flow dividers 28 shown in Figure 3. Between each adjacent pair of flow dividers 54 is provided an elongate barrier 56 which together with the flow dividers 54 provides channels 58 for incoming air 2. Each elongate barrier 56 extends between a plane through the upstream ends of adjacent flow dividers 54 and a plane through the middle regions 30 of adjacent flow dividers 54.

Downstream of each elongate barrier 56 is provided an obturator 60 extending at right angles to a plane through upstream/downstream axes of adjacent dividers 54.

The obturator 60 has a pear-shaped cross-section, with the larger end facing the downstream end of the barrier 56. This region of the obturator 60 facing the barrier 56 is provided with a groove or recess 62 extending the length of the obturator.

The components of this system, viz the flow divider 54, the barrier 56, the obturator 60, and the groove 62 in the obturator, are so arranged that particles entrained in the air stream 2 passing through channel 58 are directed into the groove 62 as scavenged dirty air 4 which then passes along the groove (ie out of the plane of Figure 6) to a scavenge port 52 as shown in Figure 5, whilst clean air 3 is directed around the obturator towards the engine. Again, advantage is take of the momentum of the particles in the dirty incoming air 2, together with coanda and other aerodynamic effects over various surfaces, to effect the separation of particles from the air.

Figure 7 shows schematically a flow divider 64 which separates a stream of incoming dirty air 2 into a stream of scavenge air 4 going into a scavenge channel 66 and clean air 3 into a channel 68 leading to the engine. The channels 66,68 are separated by a wall structure 70 which reacts with the divider 64 to induce the separation.

The divider 64 is provided downstream with an adjustable valve or flap 72 which can be used to alter the cross-section of the scavenge channel 66, and thus the ratio of scavenge air to clean air. This can be used to compensate for flow variations in the overall panel construction to allow compensation for, for example, differences in proximity to the scavenge outlet (item 52 in Figure 5) and the resultant non-desirous tendency for

different scavenge flows from different tubes (ie those closest to 52 will have high scavenge flows while those furthest away may have little or no scavenge flow). This variable area concept is also applicable to scavenge outlet 34 in the axi-symmetric tube shown in Figure 3.

The area of scavenge outlet 34 in Figure 3 may be varied by a device shown in Figures 8 and 9, the device comprising a cylindrical collar 80 which is adapted to fit on the outside of the cylindrical tube 24 and to rotate circumferentially about the axis of tube 24 over the circumferential scavenge outlet apertures 34. The collar 80 is provided with a pair of diametrically opposed circumferential slots 82 which are arranged to overlie the apertures 34. On rotation of the collar 80 about its axis the solid parts of the collar circumferentially between the slots 82 may be made to selectively occlude either wholly or in part the apertures 34, thereby providing for variation of the scavenge outlet area. It will be understood that the number of slots 82 may be varied as desired in the manufacture of the collar 80, and may vary from 1 upwards, but will preferably match the number of outlet apertures 34.

Although the non-spiral separators described above can be combined in series to operate as two independent stages for greater separation efficiency, there is scope for incorporating two successive stages within one casing. This would be more efficient that current discrete two-stage designs due to reduced pressure losses, and would be shorter and lighter.

CLAIMS

1 A particle separator for separating particulate material from an inlet air stream to a gas turbine engine, the separator comprising a panel array of at least two axisymmetric non-spiral particle separators, each separator in the array including, (a) an inlet duct, the upstream ends of the inlet ducts lying in a plane transverse of the inlet air stream, (b) first and second outlet duct means downstream of the inlet duct, the second outlet duct means providing air for the engine, and (c) an obturator arranged within the inlet duct to split the air stream in the inlet duct into first and second outlet streams, the first outlet stream having an increased content of particulate material, and the second outlet stream having a decreased content of particulate material, and to direct the first outlet stream to the first outlet duct means and the second outlet stream to the second outlet duct means.

2 A particle separator as claimed in claim 1 wherein the first outlet duct means is arranged to direct the first outlet stream to a scavenge plenum chamber.

3 A particle separator as claimed in claim 1 or 2 wherein the first outlet duct means is arranged to direct the first outlet stream at an angle to the second outlet stream.

4 A particle separator as claimed in any preceding claim wherein the inlet duct is provided with a polygonal cross-section at its upstream end and a

circular cross-section at its downstream end, there being provided a transition region in the inlet duct from one cross-section to the other.

5 A particle separator as claimed in claim 4 wherein the upstream polygonal cross-section is a polygon characterised in that a plurality of such polygons are capable of tiling a plane.

6 A particle separator as claimed in any preceding claim wherein there is provided a valve in the first outlet duct means whereby the ratio of the first outlet stream to the second outlet stream may be controlled.

7 A particle separator as claimed in claim 6 as dependent on either of claims 4 or 5 wherein the outlet duct means is provided by at least one aperture in the wall of the circular cross-section portion of the inlet duct.

8 A particle separator as claimed in claim 7 wherein the valve is provided by an apertured collar surrounding said circular cross-section portion, overlying the outlet duct means, and adapted to rotate about the circular cross-section portion, whereby solid portions of the collar may selectively occlude the outlet duct means and thereby vary the ratio of the first outlet stream to the second outlet stream.

9 A particle separator as claimed in claim 6 wherein the valve is provided by an adjustable flap.

10 A particle separator as claimed in any preceding claim wherein the second outlet duct means provides

an inlet stream to a second particle separator integrated with the first separator.

11 A particle separator for separating particulate material from an inlet air stream to a gas turbine engine, substantially as hereinbefore described with reference to Figures 3-9 of the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number
GB 9219264.0

Relevant Technical fields

(i) UK Cl (Edition K) B1T (TPFK,TPGG,TPNB)

(ii) Int Cl (Edition 5) B01D (45/04,45/06,45/12,45/16)
F02C 7/052

Search Examiner
R T HAINES

Databases (see over)

(i) UK Patent Office

(ii)

Date of Search
12 OCTOBER 1992

Documents considered relevant following a search in respect of claims 1-11

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB 2138318 A (CONDAIR AG)	1-3
X	GB 1553526 (ZELLINGER & ZOLLENBERG LTD)	1-3,5
X	GB 1101062 (GIANNOTTI ASSOC.)	1-3
X	GB 1298793 (FARR CO)	1-3,5
X	US 4469497 (LINHARDT)	1-3

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).